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Does Exchange Rate Volatility Hinder Export Growth?

Additional Evidence

Ying Qian
and
Panos Varangis

Inconsistency in the relationship between exchange rate volatility and export growth reflects differences among countries in the currency in which trade is invoiced. Also, exchange rate volatility may affect the allocation of trade more than its level.

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This paper — a product of the International Trade Division, International Economics Department — is part of a larger effort in the department to analyze the effects of the exchange rate on trade. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Dawn Gustafson, room S7-044, extension 33714 (May 1992, 42 pages).

Qian and Varangis examine the impact of exchange rate volatility on trade, using an ARCH-in-mean model. The advantages of this statistical approach over earlier approaches are that it provides more efficient coefficient estimates and it prevents the problem of spurious regressions. They applied the model to six countries, estimating both bilateral and aggregate exports.

They found exchange rate volatility to have a negative, statistically significant impact in two cases: Canadian and Japanese exports to the United States. In terms of aggregate exports, the relationship was negative but statistically insignificant for Japan and Australia; positive and statistically significant for Sweden and, to some extent, the United Kingdom; but statistically insignificant for the Netherlands. The magnitude of the impact of exchange rate volatility varied greatly — from a reduction in exports of 7.4 percent (Canada) to an increase of 5 percent (Sweden), following a 10 percent increase in volatility.

These results led to the hypothesis that the impact of exchange rate volatility may be influenced by the invoicing of exports. Exports from Canada and Japan to the United States are invoiced primarily in U.S. dollars. The same can be said of Japan's and Australia's total exports. The exports of the other countries are priced mostly in their own currency. If exports are invoiced in the exporters' currency, as is common in industrial countries, exchange rate volatility does not matter. Exporters pass price changes due to exchange rate fluctuations on to importers, who in turn pass them on to consumers. There are several reasons why consumers may be indifferent to the exchange rate risk, especially for manufactured products.

But if exports are priced in the importers' currency or a third currency, volatility matters — because both the exporter and the importer must take into account how their profits vary when considering the currency risk they face. For the exporter, the covariance between costs and revenues is likely to be smaller than for the importer. That means that while the importer or final consumer has a "natural" hedge available, the exporter does not.

Finally, one can argue that the effect of exchange rate volatility on trade is overstated, for the following reasons. Exchange rate volatility does not measure the added riskiness of a firm's portfolio. Exchange rates can provide a natural hedge in a firm's portfolio. Exchange rates may be negatively correlated with each other or with the firm's other assets. And finally, the use of forward markets can provide a useful short-term hedge.

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I. INTRODUCTION[1]

During the 1970s and 1980s, following the breakdown of the Bretton Woods system of exchange controls, there has been substantial literature generated dealing with the effects of exchange rate volatility on the volume of trade.[2] The studies dealing with this issue focus on the argument that exchange rate volatility increases the risk and uncertainty in international transactions and thus discourages trade. If market participants are risk averse, they will be willing to incur an added cost to avoid the risk associated with the exchange rate volatility. Thus, a firm's export supply (import demand) curve will shift to the left (right) in the presence of exchange rate volatility; for any quantity of exports or imports the corresponding price will be higher under exchange rate volatility (risk) than without it. In a sense, trade will be reduced similarly to a reduction following an increase in transportation costs. An IMF (1984) study cites arguments that exchange rate variability would also tend to induce macroeconomic phenomena that are undesirable, for example, inflation, constraints on government policy actions, and protectionism. Some authors have blamed the increase in exchange rate volatility for the slowdown in trade in the late 1970s but argued that this was due to the political economy effects of exchange rate variability (de Grauwe, 1987). In essence, the flexible exchange rates led to misalignments of major currencies which led, in turn, to adjustment problems in the tradable goods sectors and political pressures toward protectionism.

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[1] The authors wish to thank Ron Duncan, George Tavlas, Michael Ulan, Ken Kroner, Stan Wellisz, Vikram Nehru and George Alogoskoufis for their valuable comments and suggestions.

[2] For earlier reviews of the literature see IMF (1984) and Bailey and Tavlas (1988).

While the earlier literature focused on the negative effect of exchange rate volatility on trade, more recent studies provide explanations on why a positive effect could also be possible. Bailey, Tavlas and Ulan (1987) argue that in order to reduce volatility the authorities have to rely on measures that can be more costly than the exchange rate volatility they replace. de Grauwe (1987) argues that if exporters are sufficiently risk averse, an increase in the exchange rate volatility raises the expected marginal utility of export revenue and therefore induces them to increase exports. Finally, Caballero and Corbo (1989) showed that under perfect competition, convexity in profit functions, symmetric costs of capital adjustment, and risk neutrality, increases in exchange rate volatility will increase exports. Their argument goes as follows: when exchange rate movements are unfavorable, firms will reduce production and thus they will have more capital than optimal. When exchange rate movements are favorable, firms will produce more and have less capital than they need. Assuming a convex profit function, the potential profits foregone due to insufficient capital are higher than the losses due to underutilized capital. So profit maximizing firms will tend to overinvest, and thus export more in the face of uncertainty. The authors argue, however, that if the hypotheses about risk neutrality and symmetric costs (e.g., sunk costs) are relaxed then exports will decline with increasing exchange rate uncertainty.[3]

Exchange rate volatility can also influence export volumes and prices in hysteretic models of trade.[4] When international trade involves significant non-recoverable costs,

[3] If one introduces risk aversion and if the concavity of the utility function offsets the convexity of the profit function, exports will be negatively affected by exchange rate volatility.

[4] See Baldwin and Krugman (1989) and Dixit (1989).

exchange rate volatility can affect trade even if agents are risk neutral. However, it is not clear which way trade is affected. For example, Froot and Klemperer (1989) show that when market share matters in an oligopolistic market, exchange rate uncertainty can affect both the price and quantity of trade in either direction--regardless of risk preferences.

Despite these arguments for positive effects, the most plausible case is that exchange rate volatility has a negative impact on trade. However, the negative impact may be overstated because of the simultaneous impact of exchange rate volatility on a company's portfolio and the availability of financial instruments to hedge against currency risk.

It can be argued that exchange rate volatility per se does not measure the added impact of the foreign currency on the overall riskiness of the firm's asset portfolio. The firm may hold a portfolio of several currencies. If one exchange rate is negatively correlated with others, then its inclusion in the firm's portfolio will tend to reduce the overall portfolio risk rather than increase it. Therefore, if a company carries on production in several countries, what matters is its net exposure to exchange rate volatility; the firm's production and exports need not be influenced by the exchange rate (bilateral or multilateral) of the countries in which it produces or with which it trades. A firm may shift its exporting from a location subject to a high exchange rate volatility to a location with a lower exchange rate volatility, if this reduced its net exposure to exchange rate volatility. Thus, exchange rate volatility could have its main impact on the allocation of exports rather than on their aggregate level.

If firms hedge against exchange rate risk, one would not expect to find a strong negative effect on trade. However, most studies have not taken hedging possibilities into account. It has been argued that hedging foreign exchange risk via forward/futures markets is an imperfect and costly method of avoiding exchange rate risk.[5] So, even in the presence of forward markets for exchange rates and hedging by firms, trade is expected to be hurt. Bailey, Tavlas and Ulan (1987) argue that the existence of forward or futures markets for foreign exchange does not change the thrust of the argument, but rather reduces its quantitative significance. An IMF (1984) study argues that forward/futures markets can be used to hedge against nominal exchange rate risk in the short run (3-12 months) at small cost (thinly spread between bid and offer rates). However, long term export oriented activities would be exposed to higher and possibly unhedgeable risks.

While the majority of theoretical arguments do not deny that increased exchange rate volatility reduces trade, the empirical evidence is inconclusive to this point. The studies of Abrams (1980), Cushman (1983, 1986, 1988), Coes (1981), Akhtar and Hilton (1984), Thursby and Thursby (1987), Kenen and Rodrik (1986), Kumar and Dhawan (1991), de Grauwe (1988), and Caballero and Corbo (1989) found statistically significant evidence that exchange rate volatility does impede trade. Contrarily, the results from Bailey, Tavlas and Ulan (1986-87), Bailey and Tavlas (1988), Gotur (1985), Koray and Lastrapes (1989), Medhora (1990), IMF (1984), and Hooper and Kohlhagen (1978) could

[5] That is because, first, hedging transactions have a cost. Second, several studies have indicated that the forward rate is a poor predictor of the future spot rate--(see for example, Cumby and Obstfeld (1981), Frankel (1980), and Hakkio and Rush (1989). Third, firms cannot always plan the magnitude or timing of their foreign exchange transactions.

not find conclusive evidence that exchange rate volatility has had statistically significant deterrent effects on trade. Even in this latter group of studies, the results are inconsistent across countries; results from Kroner and Lastrapes (1991) also indicate that for some countries exchange rate volatility has a negative effect on trade but for others not.

The majority of studies rely on a standard export supply (or import demand) regression equation in which a proxy variable for exchange rate volatility is introduced on the right hand side. The sign of the coefficient determines the impact of exchange rate volatility on the trade volume. This type of test has two potential problems. First, the trade volume series employed, as well as the explanatory variables used, may be non-stationary. In such a case the regression analysis employed may give spurious results (see Phillips, 1986). The non-stationarity of trade volumes is quite plausible given the growth of trade during the last 20 years, the period used in most studies. Second, exchange rate volatility is usually measured as the moving standard deviation of past growth rates of exchange rates. This approach may incorrectly specify the stochastic process that generates exchange rates. In addition, as pointed out by Kroner and Lastrapes, the test requires a two-step procedure; first calculating the volatility and then using it in the regression. This may lead to inefficient estimators.

The purpose of our paper is to improve on the regression analysis used in previous studies by taking into account the time series properties of the variables involved and using the ARCH-in-mean (ARCH-M) model which should lead to more efficient estimators.[6] In addition, we study countries other than the traditionally studied

[6]ARCH stands for Autoregressive Conditional Heteroskedasticity. For details regarding this approach see Engle (1982).

G-5 and examine the possible implications of currency invoicing on the effect of exchange rate volatility on trade.

The remainder of this paper is structured as follows. In Section II, the testing procedure used is outlined. In Section III, the estimation results are presented and discussed. Section IV concludes.

II. TESTING PROCEDURE

The test used in the majority of the studies is based on a linear regression of the following general form:

$$Q_t=a_0+a_1Y_t+a_2RP_t+a_3V_t+U_t$$

where Q_t is the quantity of exports or imports, Y_t is a measure of real economic activity (GNP, or index of industrial production), RP_t is a measure of relative prices relevant to the analysis, V_t is a measure of volatility and U_t is a random error. Some studies add additional variables, such as a time trend or a variable to reflect consumer tastes. In this framework, a statistically significant and negative coefficient for a_3 indicates the existence of a negative relationship between volatility and trade. The most notable variations on this methodology are Koray and Lastrapes who employ the VAR approach, and Kroner and Lastrapes who use the GARCH-in-mean model.[7]

Three issues regarding the test procedure have been raised. First, how to measure exchange rate volatility? Secondly, is a measure of volatility based on nominal or real exchange rates more appropriate? Thirdly, should aggregate or bilateral trade data be the focus of the study?

Most of the studies use the moving standard deviation of the percentage change in the exchange rate as the measure of exchange rate volatility. Three other proxies for

[7]GARCH stands for Generalized Autoregressive Conditional Heteroskedasticity, and VAR for Vector Autoregressive.

exchange rate volatility are: (i) the absolute value of the percentage changes in the exchange rate (Bailey, Tavlas and Ulan); (ii) the variance of the exchange rate around a deterministic (predicted) trend (Thursby and Thursby); and (iii) measures that use information contained in the forward exchange rate concerning exchange rate expectations (Cushman, 1988). The third measure utilizes a regression of the form:

$$S_{t+1}-S_t=a+b[F_t-S_t]+e_t$$

where S_t is the spot exchange rate at time t, and F_t is the forward exchange rate for the period t + 1 at time t. Cushman then obtains the fitted values from this regression and calculates a moving standard deviation of the fitted values, to be used as a proxy for the exchange rate volatility. However, as stated above, measuring the impact of exchange rate volatility in the export equation in this way involves a two-step procedure that may lead to inefficient estimates of the coefficient on volatility term.

As regards whether to use nominal or real exchange rate data in calculating the volatility, a number of studies claim that when using real exchange rate data they get somewhat more significant results than when using nominal exchange rates (see Bailey, Tavlas and Ulan, and de Grauwe). These results are surprising in high frequency data, given that nominal and real exchange rates have moved closely together during the floating exchange rate period (see Mark, 1990 and Hakkio, 1989). We have therefore ignored this issue and use exchange rate data in nominal terms.

Some studies used bilateral while others used multilateral trade data. Cushman (1983, 1986, 1988), Kumar and Dhawan (1991), Thursby and Thursby (1987), and de Grauwe (1988) using bilateral data found negative relationships between exchange rate volatility and trade, while Hooper and Kohlhagen (1978), and Koray and Lastrapes (1989) did not. Cushman (1986) argued that omitting a "third country" in the bilateral approach may lead to a specification problem, which may bias the coefficient estimate upwards. For example, while increased dollar-deutsche mark exchange rate volatility is expected to reduce US exports to Germany, it may increase them if, say, the dollar-pound volatility is greater than the dollar-deutsche mark volatility and US exports are diverted from the United Kingdom to Germany. This problem would be avoided when a given country's aggregate exports or imports and a multilateral exchange rate risk measure is used. With the exception of Kenen and Rodrik (1986), Akhtar and Hilton (1984), and Caballero and Corbo (1989), all other studies based on aggregate data did not find significant evidence on the effects of volatility on trade. In summary then, while most studies using bilateral data found that exchange rate volatility had a negative impact on bilateral trade volume, most studies using aggregate data did not. These findings can be interpreted in favor of the argument that exchange rate volatility has effects on the allocation of trade rather on its aggregate level only.

After carefully examining the pros and cons of various analytical frameworks, we decided that our study should be based on the following considerations. There should not be any imposed beliefs as to whether exchange rate volatility affects trade volumes positively or negatively; so our model has to be general and flexible enough in its specification to take into account all the dynamics in the data generation process in the exchange rate and international trade volume variables. We decided to use both multilateral and bilateral trade and exchange rate data in order to investigate differences in the magnitude of the exchange rate volatility effects on trade.

An extended vector autoregression (model) in first differences was the statistical framework chosen given the concern for the model's generality. Trade volume, relative price, and other exogenous variables in levels would be tested for stationarity and if found not to be stationary, they would be differenced to ensure their stationarity and to avoid the spurious regression problem. Such a model is of a reduced form, encompassing many different types of structural models. It does not intend to make any explicit or implicit discrimination against any structural model; rather, it only quantifies the dynamics of the underlining "true" structural model. In addition, it allows joint estimation of relationships between volatility and trade and of how past information is related to perceived volatility, and thus avoids the problem other studies have faced in the two-step approach.

It has been observed that exchange rate movements follow a martingale process. Such an assumption implies that changes in the exchange rates in the next period are unpredictable, given observations on current and past exchange rates.[8] It has also been observed that large changes of exchange rates tend to be followed by large changes (of either sign), and small changes tend to be followed by small changes. An ARCH specification thus is very suitable to model exchange rate movements, and provides a rich class of possible parameterizations of heteroscedasticity.

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8 The assumption has received considerable empirical support; see Meese and Rogoff (1983), Frankel and Meese (1987), Dixit (1989), Diebold and Nason (1990) and Meese and Rose (1990).

It has been of interest recently to economists to estimate the autoregressive conditional heteroscedasticity (ARCH) explicitly in their various models, most noticeably in models estimating the time-varying risk premia in financial markets. A multivariate ARCH-M model, which serves as the main tool in this paper, extends the ARCH model to the multivariate environment to allow the conditional variance to affect the mean. Empirically, this implies that changes in exchange rate volatility (measured as the conditional variance) directly affect the trade volume.

Advantages of the ARCH-M model approach over other approaches can be summarized as follows. First, the risk resulting from the exchange rate volatility is explicitly modeled and included as a regressor in the trade volume equation, thus avoiding arbitrariness in defining the measure of volatility risk. Second, possible heteroscedasticity has been taken into full account in the estimation process, thus avoiding the possibility of biased estimates of the test statistics.

Specifically, the multivariate ARCH-M model in our context would be:[9]

$$a_x(L)\Delta x_t=\phi_x\Delta s_t+b_x(L)\Delta p_t+c_x(L)\Delta y_t+d_x f(h_{t+1})+e_{xt} \quad (1)$$

$$a_p(L)\Delta p_t=\phi_p\Delta s_t+b_p(L)\Delta x_t+c_p(L)\Delta y_t+d_p f(h_{t+1})+e_{pt} \quad (2)$$

$$\Delta s_t=c_{s0}+e_{st} \quad (3)$$

Where L is the backshift operator, and $a_x(L)$, $b_x(L)$, $c_x(L)$, $a_p(L)$, $b_p(L)$ and $c_p(L)$ are

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[9] See Kroner and Lastrapes (1991).

polynomials in lag operators, thus denoting the coefficient structure of the system of equations. In general, they have the form:[10]

$$a(L)=1-a_1L-a_2L^2-\ldots-a_{n_a}L^{n_a}$$
$$b(L)=b_1L+b_2L^2+\ldots+b_{n_b}L^{n_b}$$
$$c(L)=1+c_1L+c_2L^2+\ldots+c_{n_c}L^{n_c}$$

Δ is the first difference operator. x_t is real exports from the home country to the rest of the world during time t; p_t is the corresponding price of exports denominated in foreign currency; s_t is the exchange rate in terms of the foreign currency per unit of home currency; and c_{s0} is a constant. y_t is the vector of exogenous variables, which may include the constant term, domestic labor costs in real units, real foreign income, the foreign price level, and possibly some demographic or geographic variables. ϵ's are white noise stochastic processes. $f(h_{t+1})$ is the function of the expected time-varying conditional variance term of the exchange rate for t+1.

The exchange rate is specified as a random walk (equation (3)). This is consistent with the results of Meese and Rogoff (1983), Meese and Rose (1990) and Diebold and Nason (1990). This specification assumes that changes in the exchange rate are unpredictable given past observations, so that the measure of exchange rate volatility, h_t, measures the volatility of unexpected changes in the exchange rate.

Define $\epsilon_t = [\epsilon_{xt}, \epsilon_{pt}, \epsilon_{st}]$. ϵ_t follows a conditional distribution $\epsilon_t \mid \epsilon_{t-1} \ldots N(0, H_t)$. The covariance matrix of the residuals from equations (1), (2) and (3) thus is:

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10 Subscripts x and p are omitted for simplicity.

$$H_t = \begin{pmatrix} \sigma_x^2 & \sigma_{xp} & 0 \\ \sigma_{xp} & \sigma_p^2 & 0 \\ 0 & 0 & h_t \end{pmatrix} \tag{4}$$

$$h_t = \gamma_0 + \gamma_1 \sum_{i=1}^{n} w_i \epsilon_{st-i}^2$$

where σ's are unconditional variances/covariances from the respective equations. Only the exchange rate specification allows the ARCH effect, where the h_t term is based on time t, and is the weighted sum of past squared error terms. w_i is the weight, which discounts older innovations in a pre-determined consistent manner.

As can be seen from our specifications (3) and (4), the ARCH model assumes stochastic dependence between the current realization of ϵ_{st} and its past realizations. So the conditional variance of ϵ_{st} is time-varying. The function of the conditional variance of the one-step ahead exchange rate $f(h_{t+1})$ is included as the explanatory variable for export volume and export price equations (equations (1) and (2)). Also note that the exchange rate s_t is set independently from the equilibrium in the export market.[11]

An immediate distinction between our model and earlier models is that we model the export volume and price simultaneously. We believe that it would be a mis-specification if we model export supply while ignoring export prices.[12] Similar to the ambiguity of the effect of exchange rate volatility on the volume of exports, the effect of exchange rate volatility on price (denominated in foreign currency) of exports is also uncertain. For example, assuming that the foreign demand curve for home exports is

[11] This partial equilibrium approach in modeling exchange rates has been significantly used in the literature; see Dornbusch (1987).

[12] Unless the small country assumption holds.

unchanged in the face of increased volatility, if the export supply curve shifts to the left (e.g., a negative volatility effect on exports), the price of exports in the new equilibrium would increase. On the other hand, if the export supply curve shifts to the right (e.g., a positive effect of volatility on exports), the price of exports would decline. In both cases, the effect of exchange rate volatility on price has softened the impact of exchange rate volatility on the export volume.

Another advantage of our approach is that it models the time-varying volatility in ARCH form, which is consistent with the empirical implementation of rational expectation models. It is in contrast to the use of an *ad hoc* proxy for time-varying volatility, such as the simple moving average of the squared deviation from the mean, which arbitrarily sets γ_0 equal to zero and γ_1 to one.

Ideally, the econometric estimation of an ARCH model such as equations (1) through (4) should be based on the maximization of the conditional log-likelihood functions over the sample observations (see Kroner and Lastrapes). However, to overcome the time consuming effort needed in computer software programming, we propose an iterative method as an alternative to full scale simultaneous maximization which reduces the programming complexity rather significantly. The iterative approach[13] separates the coefficient estimation and the estimation of the residual covariance matrix (time-varying) into two steps.[14]

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13 See flow chart.

14 In the SAS environment.

The first step of the first round of iteration is to estimate equations (1) through (3) jointly[15] using the seemingly unrelated regression (SUR) procedure, while ignoring the term $f(h_{t+1})$ in equations (1) and (2) by setting their coefficients d_x and d_p equal to zero. The second step: (i) retrieves the error terms from the system; (ii) assembles the H_t matrix (with γ_0 and γ_1 unknown) as equation (4) requires; (iii) transforms equation (3) (to ensure the correction of heteroscedasticity) by dividing both sides of the equation by h_t;

$$\frac{\Delta s_t}{\sqrt{\gamma_0+\gamma_1\sum_{i=1}^{n} w_i e_{st-i}^2}} = \frac{c_{s0}+e_{st}}{\sqrt{\gamma_0+\gamma_1\sum_{i=1}^{n} w_i e_{st-i}^2}} \tag{5}$$

(iv) re-specifies the time-varying covariance matrix H_t as the non-time-varying unconditional covariance H (valid under the newly transformed equation (5));

$$H=\begin{pmatrix} \sigma_x^2 & \sigma_{xp} & 0 \\ \sigma_{xp} & \sigma_p^2 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

and (v) submits the transformed system of equations (1), (2) and (5) with the re-specified cross-equation covariance matrix of residuals H to a new round of estimation as in the first step (unlike in the first round of iteration, the estimation step in the second or later rounds will not set d_x and d_p equal to zero).

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15 Kroner and Lastrapes (1991) have shown that the information matrix in the ARCH-M model is not block diagonal with respect to the exchange rate equation; thus, ignoring the non-zero off-diagonal to estimate the exchange rate equation separately would yield inefficient estimates.

The iteration process will come to a stop if γ_0 and γ_1 converge to their previous estimated values.

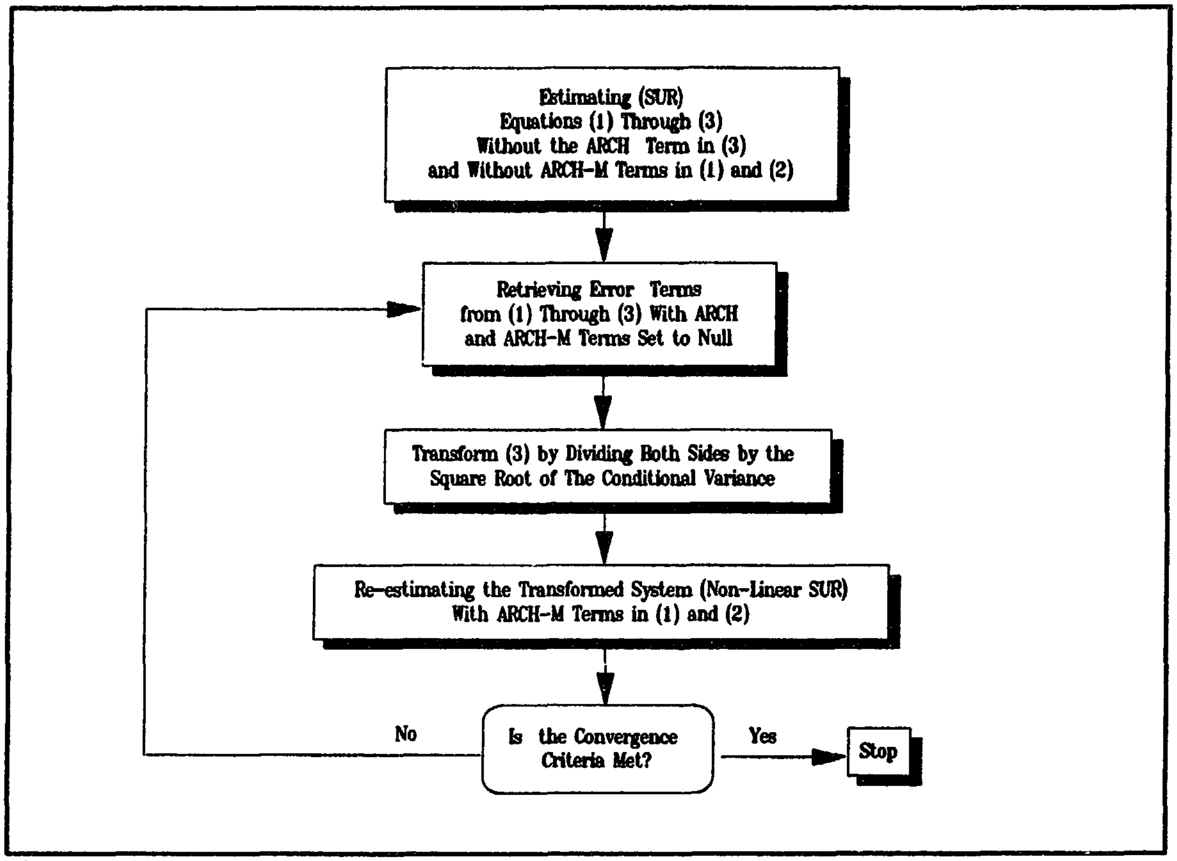

Figure 1: Flow Chart of the Estimation Process

Our proposed two-step iteration method is appropriate given the model structure represented by equations (1) through (4) for the following reasons. First, it does not lead to inconsistency in parameter estimates from either OLS or SUR by ignoring the multi-variate ARCH term in H_t, although it does impair the estimates in terms of inefficiency. Since we are not interested in test statistics in the first step, the simple SUR is sufficient to enable us to retrieve system residuals (error terms) consistently. Second, in contrast to Kroner and Lastrapes' (1991) full-fledged multi-variate GARCH model, our model is restricted in the sense that: (i) instead of GARCH, only an ARCH term is modeled in the exchange rate equation; and (ii) there are no ARCH or GARCH effects in the equations for export volume and price. Consequently, these restrictions make it possible to obtain a consistent non-time-varying covariance matrix H through transforming equations (3) to (5), and estimating equations (1), (2) and (5) jointly under SUR. Because the non-time-varying covariance matrix is used in the second or later rounds of estimation, the parameter estimates would be both consistent and efficient. Hence, our iterative method is equivalent to the procedure of conditional log-likelihood maximization.

Nevertheless, Kroner and Lastrapes' (1991) specification is more general and richer in terms of such a modeling exercise; but it is also much more computer-programming intensive. We have presumed that the marginal costs of pursuing such a more general model would outweigh the marginal gain in the correctness of the specification for our study.[16]

[16] In their empirical models of each country for the G-5 group, Kroner and Lastrapes found that out of 15 expressions to reflect the GARCH effects in export volumes and prices, 11 of them were not significant.

III. ESTIMATION RESULTS

We estimated the system of equations (1) and (3)--after correcting for heteroscedasticity in the manner described by equation (5)--for six countries characterized by different exchange rate regimes: Canada, Australia, Japan and the United Kingdom (independently floating), the Netherlands (cooperative arrangement) and Sweden (pegged to a basket of currencies). All data were obtained from the IMF/IFS data base. A brief description of the data used follows. For Canada we used the US real index of industrial production (IIP) as foreign income, the bilateral exchange rate (the US dollar over the Canadian dollar), the US CPI for foreign inflation, and Canadian real wages (deflated by the Canadian WPI).[17] For the remaining five countries we used the IIP of the G-7 countries as a proxy for foreign income, the MERM exchange rate for each country, the G-7 CPI for foreign inflation, and each country's real wages (deflated by the country's CPI).[18] For Japan and the United Kingdom the G-7 IIP and G-7 CPI was recalculated to exclude their own. In addition, we estimated Japan's bilateral export volume and export price equations with the United States which is denoted as "Japan (bilateral)" henceforth to distinguish it from "Japan" which refers to the aggregate, multilateral exports of Japan. The data were the US IIP, the Yen/US$ exchange rate, the US CPI and

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17 For the case of Canada we also estimated multilateral export volume and price equations. In the discussion, unless explicitly stated, the results presented for Canada refer to the case of bilateral trade with the US only (see Table 2b).

18 We used IIP instead of GDP as a proxy for real income because monthly observations for GDP do not exist, only quarterly and annually. Using quarterly data for the United States, the percent change of the IIP regressed on GDP gave an R^2 of 0.90, a t-statistic of 15.65 and a standard error of the regression of 0.015. The D.W. was 2.31.

Japanese real wages (deflated by the Japanese WPI). All data are monthly, covering the period 1973.1 to 1990.12 to cover the period of flexible exchange rates. Due to the length of lags used, the estimation period was 1974.1 to 1990.12.

The estimated equations are:

$$\Delta X_t = a_o + a_1 \Delta S_t + a_2 \Delta P^*_t + a_3 \Delta W_t + a_4 r_t + a_5 f(h_{t+1}) + \sum_{i=1}^{12} \delta_{xi} \Delta X_{t-i} + \sum_{i=1}^{12} \lambda_{xi} \Delta P_{t-i} + \epsilon_{xt}$$

$$\Delta P_t = \beta_o + \beta_1 \Delta S_t + \beta_2 \Delta P^*_t + \beta_3 \Delta W_t + \beta_4 r_t + \beta_5 f(h_{t+1}) + \sum_{i=1}^{12} \delta_{pi} \Delta X_{t-i} + \sum_{i=1}^{12} \lambda_{pi} \Delta P_{t-i} + \epsilon_{pt}$$

$$\Delta S_t = c_{s0} + \epsilon_{st}$$

where: x_t is the export quantity, s_t is the nominal exchange rate, P^*_t is the foreign price level, w_t is the real wage rate, r_t is the real interest rate, $f(h_{t+1})$ the measure of exchange rate volatility, the ARCH-M term, and ϵ_{xt}, ϵ_{pt}, ϵ_{st} are error terms.

All variables are in the first differences of their levels with the exception of the real interest rate. Dickey Fuller and Augmented Dickey Fuller tests for stationarity were conducted on those variables.[19] Seasonality, where indicated, was removed by regressing each variable on 12 monthly dummies and taking the residual.

The estimated equations for export quantity and export price include explanatory variables that determine export quantities and prices in equilibrium. In that sense, the

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[19] The Dickey Fuller and the Augmented Dickey Fuller test results are available upon request.

export equation is, strictly speaking, neither a supply nor a demand equation. We assumed that the exchange rate is determined independently of the equilibrium in the export market. The exchange rate and foreign price level are included to account for the relative price effects on the supply and demand for exports. The real labor cost and the real interest rate are likely to affect export supply, while foreign income is expected to affect export demand. The inclusion of all these variables in estimating export volumes and prices is standard practice in the international economics literature.

The estimation results are reported in Tables 1 through 6. For the majority of cases, the variable conventionally used to explain export prices and quantities have the right signs, although a number of them are not statistically significant. *Ceteris paribus*, the income variable should have a positive effect in both equations; the real wage should have a positive effect in the price equation but a negative sign in the export equation. The same goes for the real interest rate, foreign inflation, and the exchange rate.

Movements in the exchange rate were fully passed through to dollar export prices in the case of Canada, Sweden, and the United Kingdom (pass-through coefficients of 0.91, 0.95, 0.96, respectively) but there was significantly less than full pass-through (i.e., significantly less than one) in the case of Australia, the Netherlands, and Japan (pass through coefficients of 0.61, 0.63, and 0.68, respectively). For Japanese exports to the United States, the pass-through coefficient is 0.56. Foreign income is positive and statistically significant for the cases of Canada, Sweden, Japan, and the Netherlands in the export equation, and for Australia in the price equation. Foreign inflation is positive and statistically significant in the Australian and Netherlands price equations. However, while it was found to have a negative sign in all export equations except for Japan and the United Kingdom, foreign inflation was found statistically significant only in the cases of Sweden and the Netherlands. The real interest rate was also found to have a positive and statistically significant effect in the price equations for Sweden, the United Kingdom and the Netherlands. The lagged effect of prices on export quantities were statistically significant and negative, particularly in the first three to four lags. A puzzling result was the negative and statistically significant effect of real wages on the dollar export price in all cases except Japan. However, when we excluded the real wages from the export price equation this had no effect on the estimates of the impact of exchange rate volatility on trade. Note that real wages were the only coefficients that had the wrong sign and were statistically significant.

As regards the effect of exchange rate volatility on export quantities and prices, the results showed that for Canada, Australia, and Japan exchange rate volatility affected prices positively (except Japan) and exports negatively. However, these effects for Australia were found to be statistically insignificant, while for Canada and Japan they were only significant at the 85% confidence level (in a one-tail test) in the export equation, and for Canada only at the 90% confidence level in the price equation. When estimating the equations for bilateral trade between Japan and the United States, the negative relationship between exchange rate volatility and exports was strongly significant. For the Netherlands, the United Kingdom and Sweden, exchange rate volatility has affected exports and prices positively (except for prices in the United Kingdom). The effect on prices was found to be statistically significant in the cases of the Netherlands and Sweden, but the effect on exports was found to be statistically significant only for Sweden. Thus, our results for the effect of exchange rate volatility on prices can be regarded as consistent with the predictions of Feenstra and Kendall (1991). These authors argue that in the presence of a risk premium, the effect of exchange rate volatility on export prices is ambiguous, and may be statistically insignificant with aggregate data.

Sweden's exchange rate regime is classified in the "currency pegged" category, according to the IMF classification. Essentially, the Swedish Kronor is pegged to a basket of currencies. During the period under investigation, there were three major devaluations of the Kronor: September 1977, September 1981 and October 1982. These large devaluations led to an increase in exports. Furthermore, these devaluations increased the volatility of the exchange rate. So, one could argue that the positive and significant result we found for Sweden, i.e., increased exchange rate volatility led to an increase in exports, could have been biased by the devaluations. We tested for this by incorporating dummy variables in equation (3) that generates the exchange rate. By doing so, we were expecting to reduce the significance of the positive effect of exchange rate volatility on trade. The reported t-statistic on the ARCH-M coefficient dropped from 2.98 to 2.18 after the incorporation of the devaluation dummies, but the value of the ARCH-M coefficient did not change significantly. So even after accounting for the effects of the large devaluations, the coefficient for the impact of exchange rate volatility on exports remained positive and statistically significant.

According to these results, a 10% increase in the volatility of exchange rates will increase the volume of trade by 5% in Sweden, 2% in the Netherlands, and 0.04% in the United Kingdom, but reduce it by 7.4% for Canada, 0.7% for Japan (multilateral), 0.02% for Australia. Similarly, a 10% increase in exchange rate volatility will reduce Japanese exports to the United States by 3%. These magnitudes are significantly smaller than estimates by Caballero and Corbo and more in line with Bailey, Tavlas and Ulan, and Kroner and Lastrapes.[20]

It is interesting to note that the impact of exchange rate volatility on Japanese bilateral exports is more than four times higher than in the case of multilateral exports. Also, for Canadian multilateral data, both the impact of exchange rate volatility and its statistical significance are considerably lower than in the bilateral (with the US) case. These results may be interpreted as supporting the idea that exchange rate volatility affects more the allocation of trade rather than its overall level.

The impact of exchange rate volatility on export prices is found to be positive in five out of the seven cases. A 10% increase in exchange rate volatility will increase export prices by 2.8% for Canada, 4% for the Netherlands, 0.1% for Australia, 0.6% for Sweden, and 0.1% for Japan (bilateral), but reduce them by 0.02% for the United Kingdom and 0.3% for Japan (multilateral). The magnitude of the volatility effect is, in general, comparable for export prices and quantities. The same can be said about the

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[20] Caballero and Carbo found that a 10% increase in exchange rate volatility could lead to a 5% decline in the exports of Colombia and about a 60% decline in the exports of Thailand and Turkey. For the G-5 countries, the results of Kroner and Lastrapes ranged from a 7.25% decline of exports for the United States to a 2.66% increase in exports for France, following a 10% increase in exchange rate volatility.

statistical significance too. These results point to the impact of exchange rate volatility being only partly absorbed in the price of exports.

The ARCH model applied to the monthly exchange rate data provides a good fit for all the countries in the sample. In all cases, the γs (see equation 4) were found to be statistically significant. Furthermore, shocks in the exchange rate variance tend to be persistent. For Canada, Australia and Sweden, the coefficient of $\gamma 1$ was around 0.80, and for the Netherlands, Japan and the United Kingdom between 0.85 and 0.87. This result is consistent with the integration tests we ran, which also indicated that variance shocks tend to be permanent. Our results are compatible with those obtained by Kroner and Lastrapes who also found strongly persistent variance shocks for the United States, France and Japan.

An explanation of why we find a negative relationship between exchange rate volatility and trade volumes for Canada, Australia, and Japan, while there is a positive relationship for Sweden, the Netherlands, and the United Kingdom could be as follows. For the majority of industrial countries, their exports, particularly of manufactured products, are priced in their own currencies (see Tavlas, 1991, p. 6, and McKinnon, 1979).[21] So exchange rate volatility is not a major issue since they can pass the exchange rate changes onto the importing countries. Invoicing in the exporter's currency provides the importer with a hedge (McKinnon 1979, and Bilson, 1983). Both importers

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21 Note, however, that this pattern is influenced in the following ways: according to Tavlas (1991), the likelihood that the exporter's currency will be used in invoicing depends on the exporter's share in the world trade and the degree of product differentiation. The higher the exporter's share in world trade and the higher the degree of product differentiation, the more likely the exporter's currency will be used in invoicing.

and exporters take into account the variance of their profits when considering the currency risk they face. For the importer the covariance of revenues and costs is likely to be higher than for the exporter. We argue that there is an asymmetry in the ability of importers and exporters to hedge their exchange risk. For the exporter, costs are usually determined early in the production process and thus it is difficult to cut costs in response to an appreciation of the domestic currency. If they price in the importer's currency, exporters have to absorb the appreciation by reducing profit margins. Thus, exporters have an incentive to invoice in their own currency (McKinnon, 1979). Importers, on the other hand, can pass the exchange rate change onto the final consumer.[22] This is particularly true for trade among open economies, given that the exchange rate pass-through tends to be higher the more open the importing countries.[23]

In addition, Bailey and Tavlas (1988) and Krugman (1984) emphasized that to the extent importers bear some risk by contracting in the exporter's currency, they gain experience in dealing with it. Krugman states that importers in small countries deal with exchange rate markets as a matter of course and that these importers are obliged to be sophisticated about dealing with currency risks. Bailey and Tavlas go one step further in claiming that importers gain knowledge which increases their ability to forecast exchange rate movements better than the average participant in these markets. As a result, they argue, the currency risk can be offset by the value of this knowledge.

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[22] It is uncommon for importers to hedge their currency exposure in forward markets (Tavlas, 1991).

[23] See Collins, Meyers and Bredahl (1980).

Reasons as to why final consumers are indifferent to exchange rate volatility can be as follows. First, since consumers purchase a basket of domestic and imported goods, with the imported goods coming from many origins, exchange rates can be negatively correlated and thus provide a natural hedge. Second, even if in aggregate the consumer is exposed to exchange rate volatility, say because the various exchange rates are not negatively correlated, exchange rate movements may be offset by movements in domestic goods prices. Third, it can be argued that consumers have a real wage objective, and the wage deflator comprises both imported and domestic goods. Hence, consumers can adjust wages in order to offset changes in exchange rates. Fourth, for the majority of manufactured products (such as durable and semi-durable goods), consumers may care primarily about the level of prices rather than their volatility. This is because purchases of manufactured goods tend to be of an infrequent, discrete nature, rather than frequent and repeated.

Summing up, it can be argued that exporters have limited options by which to protect themselves against exchange rate volatility other than pricing exports in their own currency. On the other hand, importers have natural hedges available and/or more expertise in handling currency risk. Finally, consumers have various means for absorbing currency changes. There are some caveats to these arguments: first, practically speaking, there should be some cost to importers of frequently changing prices; and second, wage adjustments may not fully offset changes in exchange rates. However, the above caveats do not change the thrust of the argument that the covariance of revenues and costs are higher for the importer than for the exporter.

In the case of Canada, most of its trade is concentrated on the United States and the invoicing of these exports tends to be in US dollars. Australia also, as an exporter of primary products, tends to face dollar prices for its exports (see Tavlas, 1991, p. 7). For Japan, about 55% of its exports to the world are priced in US dollars and only 35% in Yen.[24] Also, over 80% of Japanese exports to the United States are priced in US dollars.[25] When we examined the bilateral trade of Japan with the United States, the coefficient for US$/Yen exchange rate volatility on Japanese exports to the United States was -0.3 (compared to -0.07 for Japan's total exports) and its significance measured by the t-statistic was -3.18 (compared to -1.21 for total exports).

In the case of those exporters who do not invoice in their own currencies, exchange rate volatility appears to negatively influence local currency income and profits and thus discourages exports. Currency invoicing can provide an explanation regarding the strong negative results in Caballero and Corbo who included in their study several countries that price the majority of their exports in dollars or some other importers' currencies.[26] However, we do not regard our tests of the effect of exchange rate volatility on trade as exhaustive with respect to the influence of invoicing. More work is needed in this area.

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[24] Throughout the 1970s Japanese exporters invoiced only a small percentage of their exports in yen. This was mainly because the Japanese Government was reluctant to allow the yen to become an international trading currency (Page, 1984, p. 64).

[25] See Tavlas and Ozeki (1992).

[26] The countries in the Caballero and Corbo (1989) study are: Chile, Colombia, Peru, the Philippines, Thailand and Turkey.

Finally, we checked whether the use of the ARCH-M procedure gave substantially different results than the moving standard deviation approach used in most previous studies. The ARCH-M approach yielded quite different coefficient estimates and higher t-statistics in all cases. Hence, it does matter which statistical procedure is used.

IV. CONCLUSIONS

Earlier work on the impact of exchange rate volatility on export volume and prices has used statistical techniques that overlooked the time series properties of the variables involved, possibly leading to spurious regressions, and examined the effects of exchange rate volatility on trade in a two-step manner, possibly leading to inefficient estimators. We believe that our use of the ARCH-M model to a large extent corrects these problems.

The analysis was applied to six countries, Australia, Canada, Japan, the Netherlands, Sweden, and the United Kingdom. For Australia, Canada, and Japan we found a negative relationship between exchange rate volatility and export volumes. However, only for Canada and Japan was this effect found to be even somewhat statistically significant. For the remaining three countries, we found a positive relationship, but only for Sweden, and to some extent for the United Kingdom, was the effect found to be statistically significant.

Our findings support an argument that exports which are invoiced in other than the local currency are negatively affected by exchange rate volatility. In this case, exporters have to absorb the impact of currency changes. Exports of countries which price mostly in their own currency are not affected by exchange rate volatility since the exchange rate fluctuations can be passed to the importer. However, importers have a natural hedge because they can pass the exchange rate changes onto the final consumers who have various means of absorbing them. Primary commodity exports are mostly priced in US dollars or pounds sterling. Also, trade between developed and developing countries is mostly invoiced in the currency of the developed country or in US dollars. Therefore, as a broad generalization of our results, it can be said that exchange rate volatility is likely to be more of a problem for the exports of developing countries than for industrial countries--in particular for those countries mainly exporting primary commodities, whose currencies are not tied to the currency (US dollar or pounds sterling) in which their major exports are priced, and where currency and commodity price hedging instruments are little used.

Finally, we found stronger negative relationships in the two bilateral cases: Canadian and Japanese exports to the United States. This result may also be because these exports are priced mainly in US dollars. For the case of Japan, we found that exchange rate volatility had a greater impact on bilateral than on aggregate exports. This results can be interpreted as supporting the idea that the allocation of trade among trading partners rather than its aggregate level is affected by exchange rate volatility. If a firm exports to more than one location, the volatility of a particular exchange rate *per se* does not measure the added impact of the foreign currency on the overall risk of the firm's asset portfolio. The firm may export to other locations whose exchange rates provide a natural hedge. So, increased exchange rate volatility may induce a firm or a country to shift trade from one location to another in order to minimize its total exposure to currency risk.

Table 1: AUSTRALIA

	Export Volume		Export Price	
	Coefficient	T-stat	Coefficent	T-stat
Income	0.41	0.64	0.29	3.19
Labor Cost	1.24	1.29	-0.35	-2.55
Foreign Price Level	-0.64	-1.00	0.16	1.78
Interest Rate	-0.01	-0.02	-0.04	-1.43
Exchange Rate Level	-0.18	-0.67	0.61	15.72
Exchange Rate Volatility	-0.002	-0.64	0.01	0.69

γ_1 : 0.80
(19.63)

Notes: (1) γ_1 refers to the estimated coefficient in equation (4). It measures the ARCH effect in the exchange rate. (2) The coefficients and t-statistics on the lagged export prices and lagged export volumes are omitted for clarity of the presentation.

Table 2a: CANADA (Multilateral)

	Export Volume		Export Price	
	Coefficient	T-stat	Coefficent	T-stat
Income	1.09	2.64	0.35	2.74
Labor Cost	-0.72	-1.06	-0.75	-3.50
Foreign Price Level	-1.48	-3.80	0.08	0.65
Interest Rate	-0.126	-0.92	-0.01	-0.12
Exchange Rate Level	-0.30	-0.76	0.89	7.11
Exchange Rate Volatility	-0.43	-0.91	0.20	1.36

γ_1 : 0.81
(23.82)

For notes, see Table 1

Table 2b: CANADA (bilateral with the US)

	Export Volume		Export Price	
	Coefficient	T-stat	Coefficent	T-stat
Income	2.05	4.51	0.04	0.28
Labor Cost	-0.14	-0.22	-0.76	-3.57
Foreign Price level	-0.03	-0.20	0.03	0.74
Interest Rate	-0.02	-0.15	0.01	0.24
Exchange Rate Level	-0.28	-0.72	0.91	7.31
Exchange Rate Volatility	-0.74	-1.54	0.28	1.78

γ_1 : 0.81
(20.19)

For notes, see Table 1.

Table 3a: JAPAN (multilateral)

	Export Volume		Export Price	
	Coefficient	T-stat	Coefficent	T-stat
Income	0.49	1.88	0.07	0.43
Labor Cost	0.36	1.01	-0.40	-2.47
Foreign Price Level	-0.50	-1.28	-0.13	-0.73
Interest Rate	0.54	2.95	0.08	0.90
Exchange Rate Level	-0.14	-0.90	0.68	9.83
Exchange Rate Volatility	-0.07	-1.21	-0.03	-0.92

γ_1 : 0.85
(23.39)

For notes, see Table 1.

Table 3b: JAPAN (bilateral with the US)

	Export Volume		Export Price	
	Coefficient	T-stat	Coefficent	T-stat
Income	0.02	0.18	0.04	4.89
Labor Cost	-0.79	-1.62	-0.13	-2.85
Foreign Price Level	-0.02	-0.43	0.024	4.93
Interest Rate	0.40	1.19	0.06	1.99
Exchange Rate Level	-0.11	-0.64	0.56	14.96
Exchange Rate Volatility	-0.30	-3.18	0.01	1.13

γ_1 : 0.83
(21.56)

For notes, see Table 1.

Table 4: UNITED KINGDOM

	Export Volume		Export Price	
	Coefficient	T-stat	Coefficent	T-stat
Income	0.31	1.20	0.24	0.64
Labor Cost	-0.70	-2.39	0.00	0.01
Foreign Price Level	-0.29	-1.81	-0.37	-0.98
Interest Rate	0.02	0.11	0.40	2.01
Exchange Rate Level	-0.10	-1.38	0.96	10.04
Exchange Rate Volatility	0.004	1.24	-0.002	-0.42

γ_1 : 0.86
(25.33)

For notes, see Table 1.

Table 5: NETHERLANDS

	Export Volume		Export Price	
	Coefficient	T-stat	Coefficent	T-stat
Income	1.34	4.02	-0.01	-0.14
Labor Cost	0.30	0.58	-0.27	-2.21
Foreign Price Level	-1.25	-3.44	0.19	1.84
Interest Rate	-0.03	-0.30	0.07	2.45
Exchange Rate Level	-0.36	-0.91	0.63	3.72
Exchange Rate Volatility	0.26	0.89	0.40	3.18

γ_1 : 0.87
(27.79)

For notes see Table 1

Table 6: SWEDEN

	Export Volume		Export Price	
	Coefficient	T-stat	Coefficent	T-stat
Income	1.00	1.86	-0.02	-0.35
Labor Cost	-0.60	-1.11	-0.22	-4.86
Foreign Price level	-1.17	-2.22	0.04	0.87
Interest Rate	0.14	0.91	0.03	2.47
Exchange Rate Level	0.57	1.29	0.95	25.90
Exchange Rate Volatility	0.47	2.98	0.05	3.94

γ_1 : 0.80
(19.68)

For notes see Table 1.

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